MOTOROLA SOLUTIONS

COMPUTATIONAL EME COMPLIANCE ASSESSMENT OF THE DIGITAL VEHICULAR REPEATER (DVR VHF), MOBEXCOM DVRS VHF (DQPMDVR3000P) AND COMPANION APX SERIES MODEL M37TXS9PW1AN (HUW1001A) MOBILE RADIO.

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Introduction

This PCII report summarizes the computational [numerical modeling] analysis performed to document compliance of the DVR VHF, model # MOBEXCOM DVRS VHF (DQPMDVR3000P) with FCC ID # LO6-DVRSVHF interfaced with, and transmitting simultaneously with Companion mobile radio, model # M37TXS9PW1AN (HUW1001A) and vehicle-mounted antennas with the US Federal Communications Commission (FCC) guidelines for human exposure to radio frequency (RF) emissions. The devices operate in the following frequency bands:

Regions	Device	Bands	Frequency Band (MHz)
FCC US	DVR VHF	VHF band	150.8 – 173.4
	Companion Mobile	LMR UHF1	406.1 – 470

This computational analysis supplements the measurements conducted to evaluate the compliance of the exposure from this DVR and Companion mobile radio with respect to applicable *maximum permissible exposure* (MPE) limits. All test conditions (26 in total) that did not conform to applicable MPE limits were analyzed to determine whether those conditions complied with the *specific absorption rate* (SAR) limits for general public exposure (1.6 W/kg

averaged over 1 gram of tissue and 0.08 W/kg averaged over the whole body. Exceptions are the parts of the human body treated as extremities, such as hands, wrists, feet and ankles where the limit is 4 W/kg for SAR averaged over 10 gram of tissue) set forth in FCC guidelines, which are based on the IEEE C95.1-1999 standard [1]. With SAR simulation reduction consideration, total 18 test conditions (with 36 independent simulations) had been performed addressing exposure of back seat passenger to the DVR VHF repeater with trunk-mounted antennas and Companion mobile radio (UHF R1) with roof-mount antennas.

For all simulations a commercial code based on Finite-Difference-Time-Domain (FDTD) methodology was employed to carry out the computational analysis. It is well established and recognized within the scientific community that SAR is the primary dosimetric quantity used to evaluate the human body's absorption of RF energy and that MPE limits are in fact derived from SAR. Accordingly, the SAR computations provide a scientifically valid and more relevant estimate of human exposure to RF energy.

Method

The simulation code employed is XFDTD™ v7.6.0, by Remcom Inc., State College, PA. This computational suite provides means to simulate the heterogeneous full human body model defined according to the IEC/IEEE 62704-2-2017 standard and derived from the so-called Visible Human [2], discretized in 3 mm voxels. The IEC/IEEE 62704-2-2017 standard dielectric properties of 39 body tissues are automatically assigned by XFDTD™ at any specific frequency. The "seated" man model was obtained from the standing model by modifying the articulation angles at the hips and the knees. Details of the computational method and model are provided in the Appendix A to this report. The evaluation of the computational uncertainties and results of the benchmark validations are provided in the Appendix B attached to this report. The XFDTD code validation performed according to IEEE/IEC 62704-1:2017 standard by Remcom Inc., is provided in conjunction with this report.

The car model has been imported into XFDTD™ from the CAD file of a sedan car having dimensions 4.98 m (L) x 1.85 m (W) x 1.18 m (H), and discretized with the minimum resolution of 3 mm and the maximum resolution of 8 mm. The Figure 1 below show both the CAD model and the photo of the actual car This CAD model has been incorporated into the IEC/IEEE 62704-2-2017 standard.

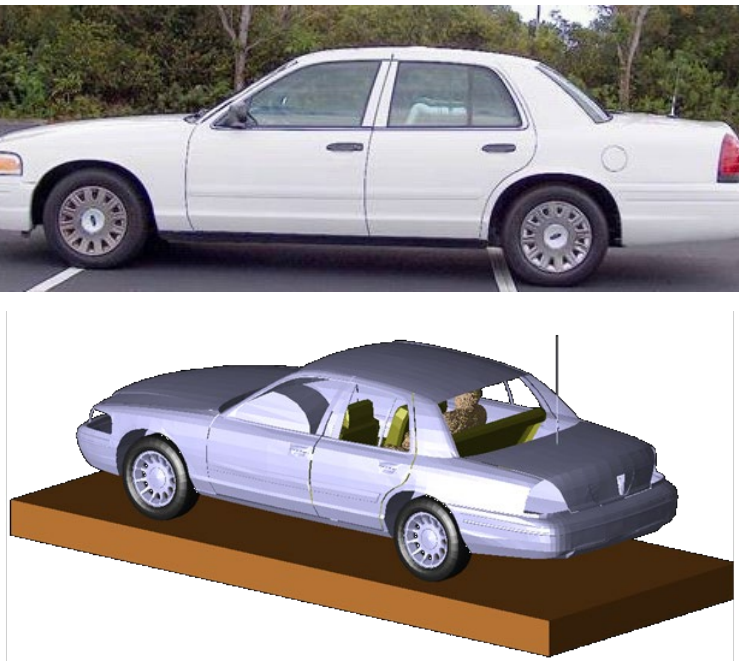


Figure 1: The photo picture of the car used in field measurements and the corresponding CAD model used in simulations

For passenger exposure, Companion mobile antenna position is on the roof and DVR VHF repeater antenna position is on the trunk. The distance of trunk mounted antenna from the passenger head when the passenger is located in the center of the back seat was set at 85 cm, to replicate the experimental conditions used in MPE measurements. Figure 2 shows some of the XFDTD™ computational models used for passenger (back seat) exposure to trunk mounted antennas.

According to the IEC/IEEE 62704-2-2017 standard for exposure simulations from vehicle mount antennas the lossy dielectric slab with 30 cm thickness, dielectric constant of 8 and conductivity of 0.01 S/m has been introduced in the computational model to properly account for the effect of the ground (pavement) on exposure.

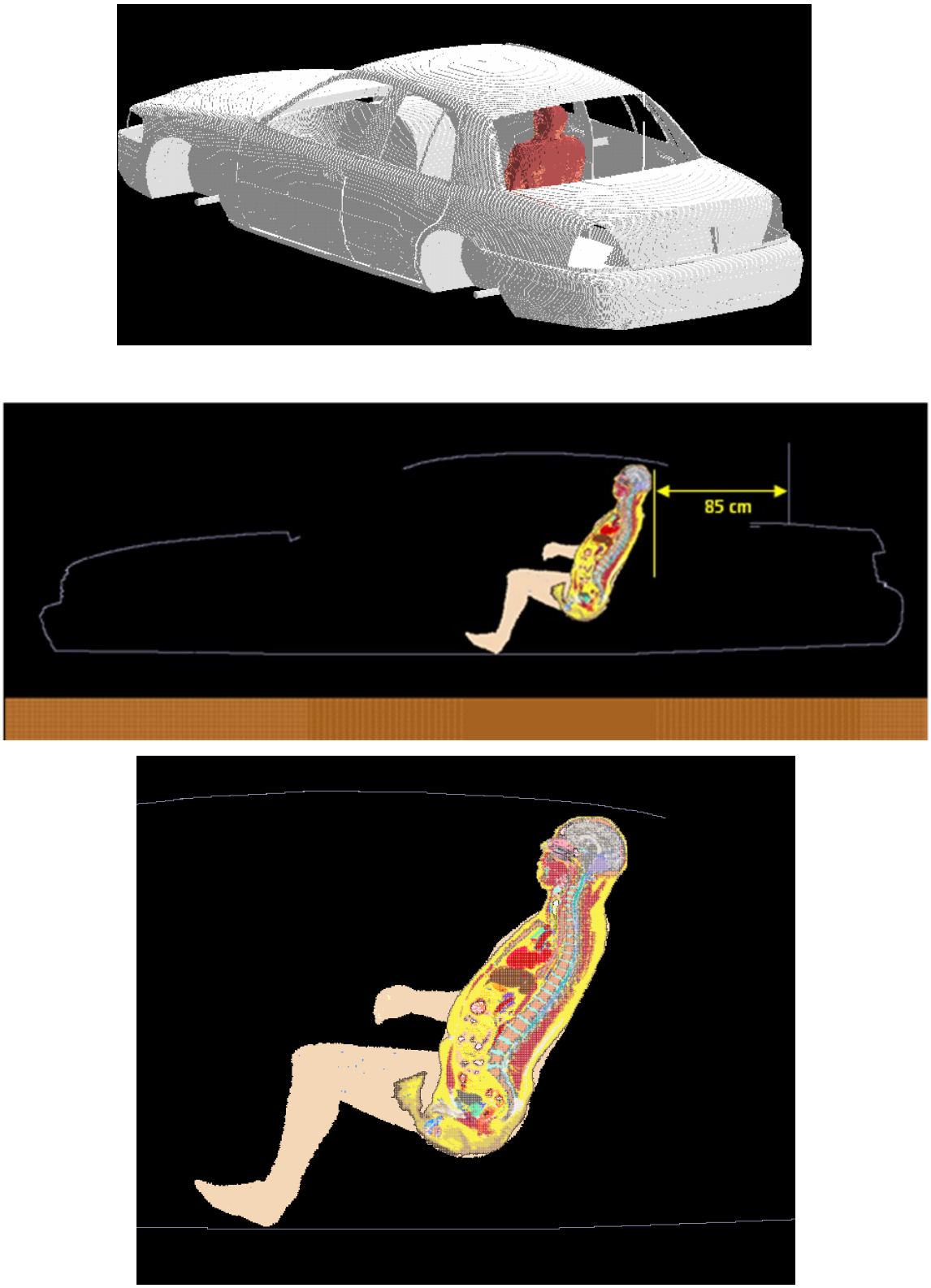


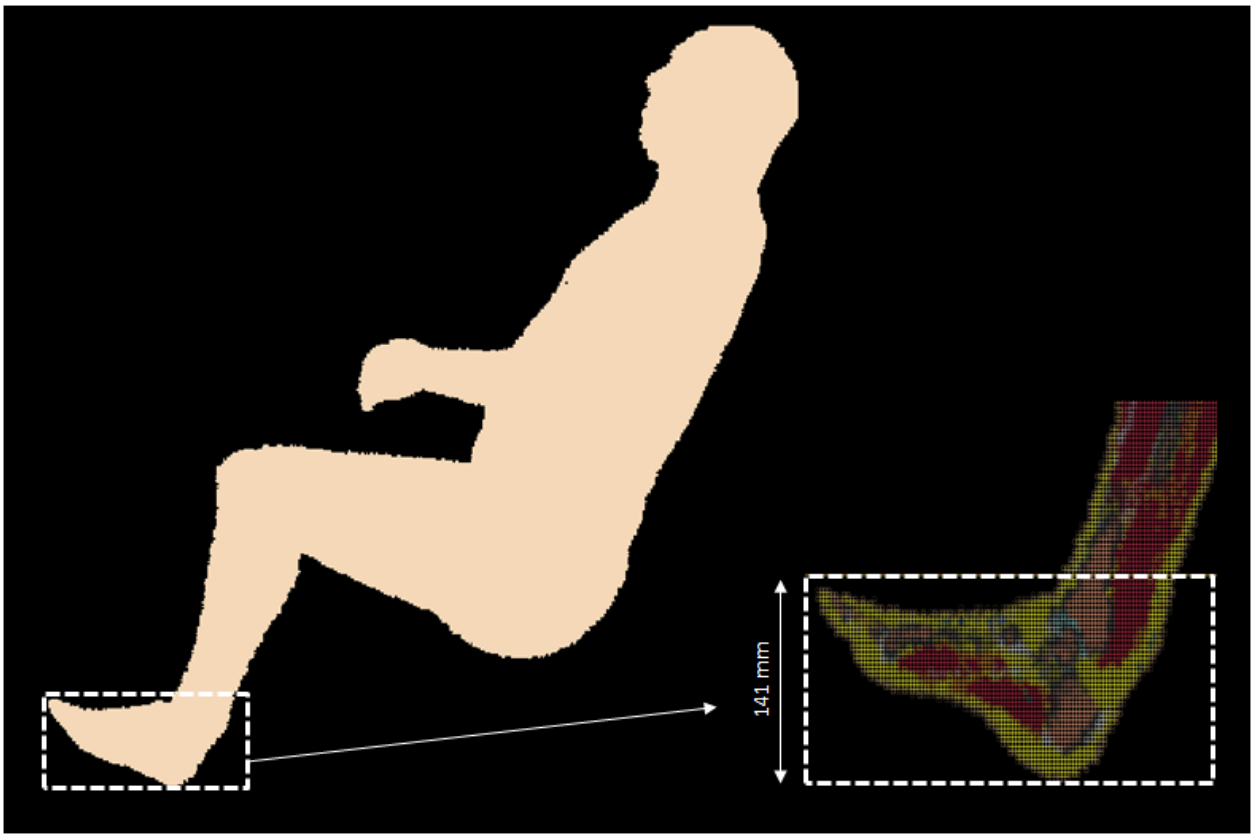
Figure 2: Passenger (back seat) model exposed to a trunk-mount antenna: XFDTD geometry. The antenna is mounted at 85 cm from the passenger located in the center of the back seat.

The computational code employs a time-harmonic excitation to produce a steady state electromagnetic field in the exposed body. Subsequently, the corresponding SAR distribution is automatically processed in order to determine the whole-body, 1-g and 10-g average SAR. The maximum average output power from DVR VHF repeater is 6W and Companion mobile radio antenna 120W (UHF R1). Since the ohmic losses in the car materials, as well as the mismatch losses at the antenna feed-point are neglected, and source-based time averaging (100% talk time) for DVR VHF repeater and (50% talk time) for Companion mobile radio were employed, all computational results are normalized to full average net output power of DVR VHF repeater, i.e., 6 W and half the average net output power of Companion radio, i.e., 60W (UHF R1); less the corresponding minimum insertion loss in excess of 0.5 dB of the feed cables supplied with the antennas. This power normalization is in accordance with the IEC/IEEE 62704-2-2017 standard.

SAR in the extremities

As described in the introduction, the human body extremities (hands, wrists, feet and ankles) are subject to a separate SAR limit (4 W/kg for SAR averaged over 10 gram of tissue for general population) set forth in FCC guidelines. Compliance with this SAR limit was evaluated in the configurations where the peak 1-g SAR exceeded 1.6 W/kg and its location occurred within an extremity region. In those cases, the peak 10-g SAR was computed in the respective extremity region and the peak 1-g SAR was computed within the remainder of the exposed body (i.e. the body excluding that extremity). It should be noted that a separate compliance evaluation for extremities was not conducted in all other cases where the peak 1-g SAR in the entire body was below 1.6 W/kg, because the peak 10-g SAR is always lower than the peak 1-g SAR and therefore would be indeed compliant with the 4 W/kg 10-g SAR limit.

The XFDTD software used for exposure simulations allows definition of the SAR averaging region to only include the tissues only within a predefined portion of the body. The figure below illustrates the extremity region (right foot ankle) defined in the applicable configurations where the peak 10-g SAR was evaluated and which was therefore excluded from the evaluation of peak 1-g SAR.


141 mm

Results of SAR computations for car passengers

The test conditions requiring SAR computations are summarized in Table 1 (DVR VHF, 100% talk time) and Table 2 (Companion mobile, 50% talk time), together with the antenna data, the SAR results, and power density (P.D.) as obtained from the measurements in the corresponding test conditions. The conditions are for antennas mounted on the trunk (DVR VHF) and on the roof (Companion mobile). The antenna length in Table 1 & 2 includes the 1.8 cm magnetic mount base used in measurements to position the antenna on the vehicle. The same length was used in simulation model.

The passenger is located in the center or on the side of the rear seat corresponding to the respective configurations defined in the IEC/IEEE 62704-2-2017 standard.

All the transmit frequency, antenna length, and passenger location combinations reported in Table 1 & 2 have been simulated individually. These tables also include the interpolated adjustment factor and corresponding SAR scaled values following requirement of the IEC/IEEE 62704-2-2017 standard.

Table 1 (configurations exceed FCC MPE limits):
Results of the Computations and Adjusted SAR for passenger (back seat) exposure of DVR VHF repeater (100% talk-time)

Mount Location	Antenna Kit#	Antenna Length (cm)	Freq (MHz)	P.D. (mW/cm^2)	Exposure Location	Computations SAR (W/kg)		Interpolated Adjustment Factors		Adjusted SAR Results (W/kg)	
						1 g	WB	1 g	WB	1 g	WB
Trunk	HAD4008A, 1/4 Wave (150.8-162MHz)	47.3	156.4000	0.14	Back Center	0.12	0.007	1.91	2.41	0.23	0.017
					Back Side	0.15	0.006	4.15	2.99	0.63	0.018
			162.0000	0.23	Back Center	0.16	0.007	1.92	2.42	0.31	0.018
					Back Side	0.16	0.006	4.11	2.98	0.67	0.019
Trunk	HAD4009A, 1/4 Wave (162-174MHz)	44.8	162.0000	0.17	Back Center	0.16	0.008	1.92	2.42	0.31	0.018
					Back Side	0.17	0.007	4.11	2.98	0.68	0.020
			167.7000	0.16	Back Center	0.13	0.006	1.93	2.42	0.25	0.015
					Back Side	0.17	0.005	4.07	2.98	0.70	0.016
			173.4000	0.19	Back Center	0.10	0.005	1.94	2.43	0.19	0.013
					Back Side	0.13	0.005	4.03	2.97	0.52	0.015

Table 2 (configurations exceed FCC MPE limits):
Results of the Computations and Adjusted SAR for passenger (back seat) exposure of Companion mobile radio (50% talk-time) – UHF1 Band

Mount Location	Antenna Kit#	Antenna Length (cm)	Freq (MHz)	P.D. (mW/cm ^2)	Exposure Location	Computations SAR (W/kg)		Interpolated Adjustment Factors		Adjusted SAR Results (W/kg)	
						1 g	WB	1 g	WB	1 g	WB
Roof	HAE6010A, 1/2 Wave (380-433MHz)	65.3	406.5000	0.12	Back Center	0.33	0.009	2.41	1.81	0.80	0.017
					Back Side	0.51	0.010	1.60	2.83	0.81	0.027
			419.5000	0.07	Back Center	0.67	0.009	2.47	1.81	*1.65	0.017
					Back Side	0.32	0.011	1.63	2.85	0.52	0.032
			432.9875	0.09	Back Center	0.36	0.010	2.53	1.81	0.90	0.018
					Back Side	0.31	0.007	1.66	2.87	0.52	0.020
Roof	HAE6012A, 1/4 Wave (380-433MHz)	20	406.5000	0.07	Back Center	0.29	0.009	2.41	1.81	0.70	0.016
					Back Side	0.57	0.010	1.60	2.83	0.92	0.030
			419.5000	0.07	Back Center	0.55	0.008	2.47	1.81	1.35	0.015
					Back Side	0.25	0.010	1.63	2.85	0.40	0.029
			432.9875	0.04	Back Center	0.27	0.009	2.53	1.81	0.69	0.015
					Back Side	0.22	0.006	1.66	2.87	0.37	0.017

Note: *Peak average SAR location at ankle of the passenger. (Refer to SAR in the extremities)

SAR simulation reduction considerations

Per Response to Inquiry to FCC (Tracking Number 528198), for a particular antenna that has more than one configuration which exceeds the MPE limit, SAR simulation shall begin with the worst case configuration (mount location and frequency channel). If the SAR value is less than 50% of the limit, no further SAR evaluation is needed for that antenna.

If the worst case configuration SAR value is above 50% of the limit, SAR simulation shall be done on the subsequent worse configuration (ranked in descending MPE percentage to limit). If the subsequent SAR value is below 75% of the limit, no further SAR evaluation is needed for that antenna, otherwise the SAR simulations for the remaining antenna configurations shall continue until the SAR value is below 75% of the limit.

Table 3 below list all the configurations that did not conform to applicable MPE limits (ranked in descending MPE percentage to limit) and apply SAR simulation reduction consideration as mentioned above.

Table 3: SAR Simulation Reduction Considerations for Passenger (back seat)

DVRS VHF		APX 8500 HP Mobile		Combine MPE (%)	Exposure Location	DVRS VHF Adjusted SAR Results (W/kg)		APX 8500 HP Mobile Adjusted SAR Results (W/kg)		Combine Adjusted SAR Results (W/kg)	
Antenna Kit#	Freq (MHz)	Antenna Kit#	Freq (MHz)			1g	WB	1g	WB	1g	WB
HAD4008A	162.0000	HAE6010A	406.5000	163.21	Back Center	0.31	0.018	0.80	0.017	1.11	0.035
					Back Side	0.67	0.019	0.81	0.027	1.48	0.046
	162.0000		432.9875	147.61	Back Center	0.31	0.018	0.90	0.018	1.21	0.036
					Back Side	0.67	0.019	0.52	0.020	1.19	0.039
	162.0000		419.5000	141.31	Back Center	0.31	0.018	1.65	0.017	**1.96** Note (1), (2)	0.035
					Back Side	0.67	0.019	0.52	0.032	1.19	0.051
	156.4000		406.5000	119.61	Back Center	0.23	0.017	0.80	0.017	1.03	0.034
					Back Side	0.63	0.018	0.81	0.027	1.44	0.045
	156.4000		432.9875	104.01	Back Center	0.23	0.017	0.90	0.018	1.13	0.035
					Back Side	0.63	0.018	0.52	0.020	1.15	0.038
HAD4008A	162.0000	HAE6012A	406.5000	144.51	Back Center	0.31	0.018	0.70	0.016	1.01	0.034
					Back Side	0.67	0.019	0.92	0.030	1.59	0.049
	162.0000		419.5000	141.61	Back Center	0.31	0.018	1.35	0.015	**1.66** Note (1), (2)	0.033
					Back Side	0.67	0.019	0.40	0.029	1.07	0.048
	162.0000		432.9875	130.21	Back Center	0.31	0.018	0.69	0.015	1.00	0.033
					Back Side	0.67	0.019	0.37	0.017	1.04	0.036
	156.4000		406.5000	100.91		The 3rd highest MPE configuration has SAR below 75% of the limit					
HAD4009A	173.4000	HAE6010A	406.5000	140.7	Back Center	0.19	0.013	0.80	0.017	0.99	0.030
					Back Side	0.52	0.015	0.81	0.027	1.33	0.042
	162.0000		406.5000	134.6	Back Center	0.31	0.018	0.80	0.017	1.11	0.035
					Back Side	0.68	0.020	0.81	0.027	1.49	0.047
	167.7000		406.5000	128.7	Back Center	0.25	0.015	0.80	0.017	1.05	0.032
					Back Side	0.70	0.016	0.81	0.027	1.51	0.043
	173.4000		432.9875	125.1	Back Center	0.19	0.013	0.90	0.018	1.09	0.031
					Back Side	0.52	0.015	0.52	0.020	1.04	0.035
	162.0000		432.9875	119.0		The 4th highest MPE configuration has SAR below 75% of the limit					
	173.4000		419.5000	118.8							
	167.7000		432.9875	113.1							
	162.0000		419.5000	112.7							
	167.7000		419.5000	106.8							
HAD4009A	173.4000	HAE6012A	406.5000	122.0	Back Center	0.19	0.013	0.70	0.016	0.89	0.029
					Back Side	0.52	0.015	0.92	0.030	1.44	0.045
	173.4000		419.5000	119.1	Back Center	0.19	0.013	1.35	0.015	1.54	0.028
					Back Side	0.52	0.015	0.40	0.029	0.92	0.044
	162.0000		406.5000	115.9	Back Center	0.31	0.018	0.70	0.016	1.01	0.034
					Back Side	0.68	0.020	0.92	0.030	**1.6** Note (1)	0.050
	162.0000		419.5000	113.0	Back Center	0.31	0.018	1.35	0.015	**1.66** Note (1), (2)	0.033
					Back Side	0.68	0.020	0.40	0.029	1.08	0.049
	167.7000		406.5000	110.0	Back Center	0.25	0.015	0.70	0.016	0.95	0.031
					Back Side	0.70	0.016	0.92	0.030	**1.62** Note (1)	0.046
	173.4000		432.9875	107.7	Back Center	0.19	0.013	0.69	0.015	0.88	0.028
					Back Side	0.52	0.015	0.37	0.017	0.89	0.032
	167.7000		419.5000	107.1		The 6th highest MPE configuration has SAR below 75% of the limit					
	162.0000		432.9875	101.6							

Notes:

(1) Refer to Combined SAR Simulation Method.
(2) Refer to SAR in the extremities.

Combined SAR Simulation Method

The sum of the peak SAR values may over estimate the actual combined SAR because the corresponding peaks from different transmitters are frequently not collocated within the exposed human body. When the sum of the peak SAR values is greater than the limit, the actual combined peak average SAR may still be compliant. To determine compliance, the combined SAR distribution may be computed by summing up the individual SAR distributions from different transmitters and evaluating the corresponding combined peak average SAR value. Accordingly, for such configurations the combined SAR was evaluated with the DVRS VHF antenna position on the trunk and Companion mobile position on the roof in same simulation. Figure 3 shows XFDTD™ computational models used for passenger (back seat) exposure to trunk and roof mounted antennas simultaneously.

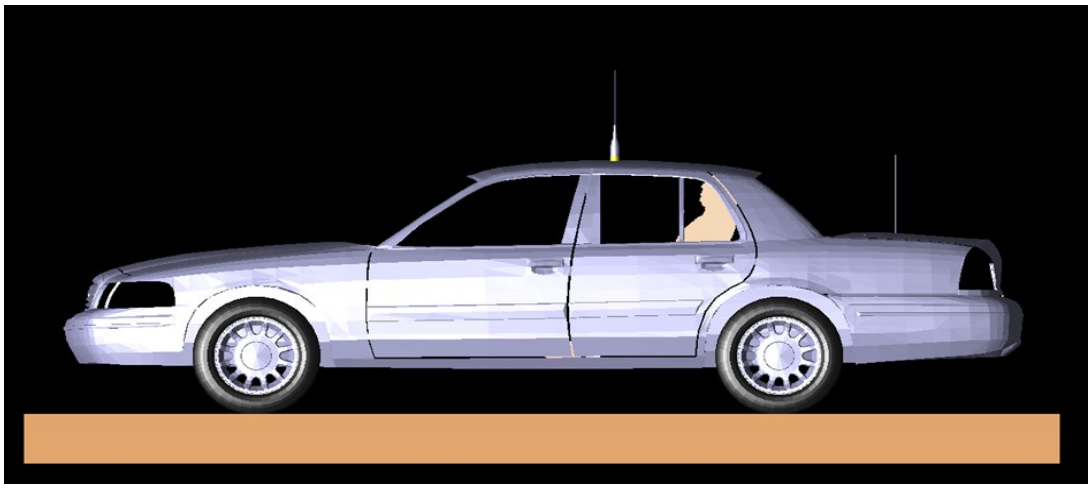


Figure 3: Passenger (back seat) model exposed to a roof-mount and trunk-mounted antennas

Compliance with the 1-g average SAR limit of 1.6W/kg and 10-g SAR limit of 4.0 W/kg (extremities) demonstrated through combined SAR distribution evaluation. Table 4 presents the maximum combined SAR simulation results.

Table 4: Combined SAR Simulation Results

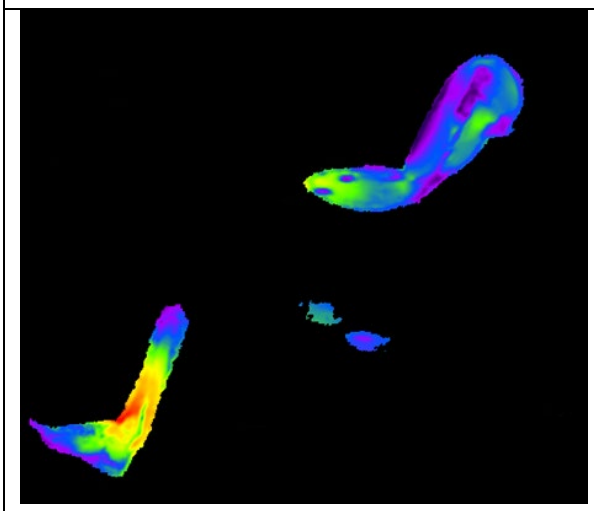
DVRS VHF		APX 8500 HP Mobile		Exposure Condition	Combined SAR Simulation Result (W/kg)		Remarks
Antenna Kit#	Freq (MHz)	Antenna Kit#	Freq (MHz)		1g (1)	10g (2)	
HAD4008A	162.0000	HAE6010A	419.5000	Back Center		1.12	Peak average SAR location in the extremity (right foot ankle) of the passenger. *(refer to SAR Distribution Plot # 1)*
					1.50		Peak average SAR in the body excluding the extremity (right foot ankle)
HAD4008A	162.0000	HAE6012A	419.5000	Back Center		0.92	Peak average SAR location in the extremity (right foot ankle) of the passenger. *(refer to SAR Distribution Plot # 2)*
					1.24		Peak average SAR in the body excluding the extremity (right foot ankle)
HAD4009A	162.0000	HAE6012A	406.5000	Back Side	0.92		
HAD4009A	162.0000	HAE6012A	419.5000	Back Center		0.93	Peak average SAR location in the extremity (right foot ankle) of the passenger. *(refer to SAR Distribution Plot # 3)*
					1.24		Peak average SAR in the body excluding the extremity (right foot ankle)
HAD4009A	167.7000	HAE6012A	406.5000	Back Side	1.05		

Note:

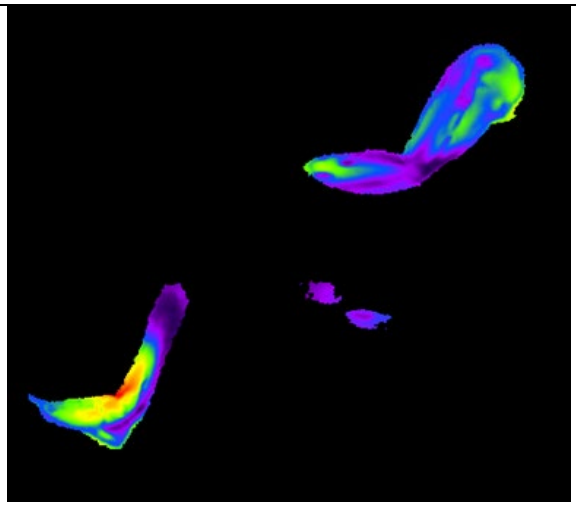
(1) SAR limit for general population/uncontrolled exposure is 1.6 W/kg for the peak spatial-average SAR averaged over any 1 gram of tissue. Exceptions are the part of the human body treated as extremities, such as hands, writs, feet, ankle, where the limit is 4 W/kg for the peak spatial-average SAR averaged over any 10 grams of tissue [refer to FCC rules part 47CFR § 1.1310 (c)]

(2) SAR limit for general population/uncontrolled exposure is 4 W/kg for the peak spatial-average SAR averaged over any 10 gram of tissue in the extremities (hands, wrists, feet and ankles). Refer to SAR in the extremities.

SAR Distribution Plot# 1 (Passenger Back Center):

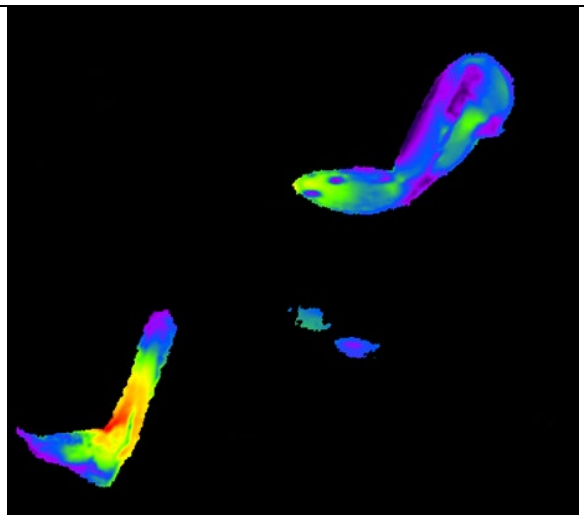


DVR VHF HAD4008A antenna (162 MHz)

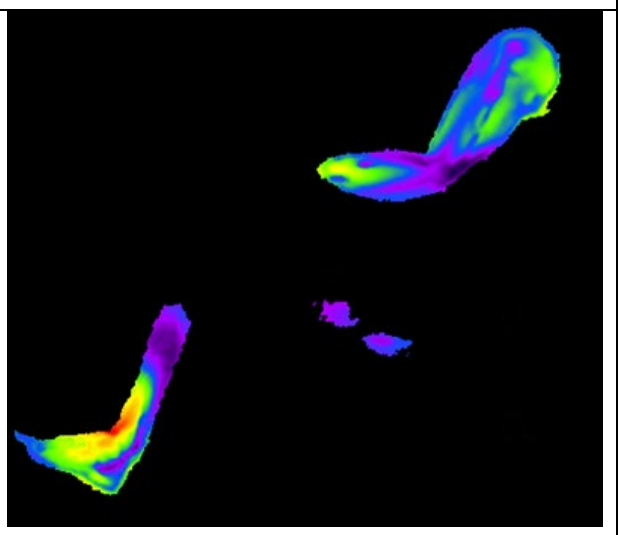


APX 8500 HP Mobile HAE6010A antenna (419.5 MHz)

SAR Distribution Plot# 2 (Passenger Back Center):

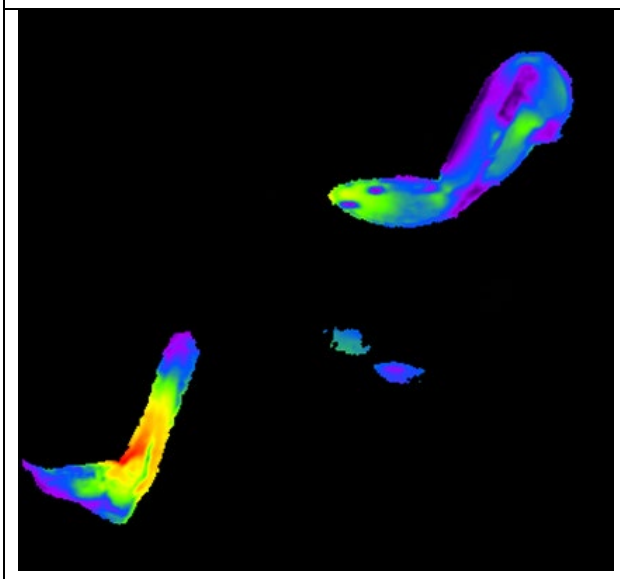


DVR VHF HAD4008A antenna (162 MHz)

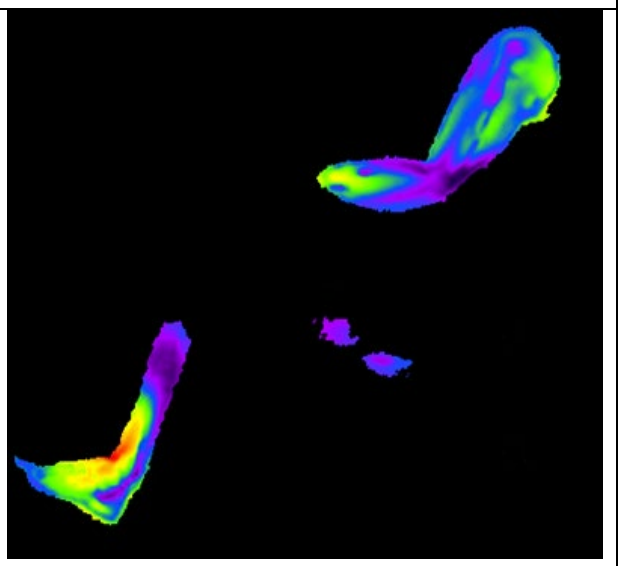


APX 8500 HP Mobile HAE6012A antenna (419.5 MHz)

SAR Distribution Plot# 3 (Passenger Back Center):



DVR VHF HAD4009A antenna (162 MHz)



APX 8500 HP Mobile HAE6012A antenna (419.5 MHz)

Results of SAR computations for combined exposure

From all simulated results the worst case peak SAR values were identified for both DVR VHF and Companion mobile radio exposure and then combined to produce the composite peak SAR value in corresponding locations of the human body model. Table 5 and Table 6 present the worst case composite peak SAR value.

Table 5: Worst case peak 1-g average SAR for passenger exposure conditions and combined 1-g average SAR from simultaneous exposure.

	Passenger location	DVR VHF [W/kg]	mobile radio [W/kg]	Total [W/kg]
FCC US	Back Center	0.19	1.35	1.54
	Back Side	0.67	0.92	1.59

Table 6: Worst case peak whole body average SAR for passenger exposure conditions and combined whole body average SAR from simultaneous exposure.

	Passenger location	DVR VHF [W/kg]	mobile radio [W/kg]	Total [W/kg]
FCC US	Back Center	0.018	0.018	0.036
	Back Side	0.019	0.032	0.051

From Table 5 and Table 6 the maximum combined peak 1-g SAR is 1.59 W/kg, less than the 1.6 W/kg limit, while the maximum combined whole-body average SAR is 0.051 W/kg, less than the 0.08 W/kg limit.

The overall maximum combine peak 10-g SAR in the extremity (right foot ankle) is 1.12 W/kg, less than the 4 W/kg limit.

Conclusions

Under the test conditions described for evaluating passenger exposure to the RF electromagnetic fields emitted by vehicle-mounted antennas used in conjunction with these mobile radio products, the present analysis shows that the computed SAR values are compliant with the US FCC exposure limits for the general public.

References

[1] IEEE Standard C95.1-1999. *IEEE Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields*, 3 kHz to 300 GHz.

[2] http://www.nlm.nih.gov/research/visible/visible_human.html